COSEWIC
Assessment and Status Report

on the

Nuttall's Sheep Moth
Hemileuca nuttalli

in Canada

ENDANGERED
2015

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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Nuttall's Sheep Moth — Photo provided by author.

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COSEWIC
Assessment Summary

Assessment Summary – November 2015

Common name
Nuttall's Sheep Moth

Scientific name
Hemileuca nuttalli

Status
Endangered

Reason for designation
This large, showy and conspicuous moth is restricted to Antelope-brush habitat in the Okanagan Valley of British Columbia. That habitat type has declined considerably in quality and extent in the past century and remains under threat due to continued conversion to viticulture, residential and commercial development, and impact of wildfires. This is a rare moth in Canada: very few have been observed since the first record in 1920. Potentially large fluctuations in the population size may affect its long-term viability.

Occurrence
British Columbia

Status history
Designated Endangered in November 2015.

COSEWIC
Executive Summary

Nuttall's Sheep Moth
Hemileuca nuttalli

Wildlife Species Description and Significance

Nuttall's Sheep Moths (*Hemileuca nuttalli*) are large members of the wild or giant silk moth family (Saturniidae). Adults of both sexes have forewing lengths of 32-39 mm with white to pale yellow forewings and bright yellow hindwings framed by a pattern of thick black markings. Larvae are spiny and black, with the final instars approximately 50 mm in length.

Distribution

The global range of Nuttall's Sheep Moth is from the extreme southern portion of the Okanagan Valley in British Columbia, southward to northern Arizona and New Mexico. In Canada, it has been recorded from the south Okanagan Valley from three general areas: 1) Osoyoos, 2) Oliver (precise site unknown), and 3) Vaseux Lake. The most recent records for the species are 2002 near Vaseux Lake and 1986 at Haynes' Lease Ecological Reserve (approximately 8 km north of Osoyoos). It is unknown if the Haynes' Lease occurrence is the same location as historical records labelled 'Osoyoos' and the precise location of the Oliver record is unknown. Targeted surveys for adults at six sites in 2009 and for larvae at 16 sites in 2014 were unsuccessful. The targeted searches in 2014 included the 2002 site.

Habitat

In Canada, Nuttall's Sheep Moth is found in the bunchgrass shrub-steppe on dry, open slopes at low elevations where the only known Canadian larval host plant, Antelope-brush (*Purshia tridentata*), is most abundant. The main habitat is the Antelope-brush/Needle and Thread Grass plant community, which is fragmented by habitat loss; less than 33% of its historical mapped distribution remains in approximately 3200 ha in the Okanagan Valley.

Biology

Nuttall's Sheep Moth is univoltine and may have a life cycle that spans 1 – 2 years. The eggs are laid on the host plants in late summer and overwinter, typically hatching in late April or May the following spring. Early instar larvae are gregarious, while later instar larvae are solitary. The 5th instar larva creates a cocoon in leaf litter or a shallow burrow, and the adult emerges later that season or possibly the following year. In Canada, the known flight period is August through early September, although individual moths have shorter life spans (adults do not feed). Adults are diurnal with a peak of activity in the afternoon, and both sexes are rapid, fast fliers. Perched females emit pheromones to attract potential mates.

Population Sizes and Trends

There is insufficient information to determine Nuttall's Sheep Moth population sizes or trends. Thousands of larvae were observed near Vaseux Lake in 1976, and the species was last observed there in 2002. Nuttall's Sheep Moth was last observed at Haynes' Lease in 1986 despite repeated surveys. No population trend data are available but apparently suitable Antelope-brush habitat in the Okanagan Valley has significantly declined in quality, area and extent.

Threats and Limiting Factors

Cumulative habitat loss, degradation, and fragmentation from agriculture (mainly vineyards and orchards) as well as residential and commercial development are the most significant threats to Nuttall's Sheep Moth populations in Canada.

Protection, Status and Ranks

Nuttall's Sheep Moths have no formal protection or status in Canada. It is not ranked by the BC Conservation Data Centre and is considered globally secure.

TECHNICAL SUMMARY

Hemileuca nuttalli

Nuttall's Sheep Moth Hémileucin de Nuttall

Range of occurrence in Canada (province/territory/ocean): British Columbia

Demographic Information

Generation	1-2 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes. Inferred due to loss of Antelope-brush habitat
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline a)clearly reversible and b) understood and c) ceased? • Decline is inferred through habitat loss; it is not easily reversible and is not ceased.	a. No b. Yes c. No
Are there extreme fluctuations in number of mature individuals? • Historical and recent records have not been abundant. However, observations of hundreds of larvae suggest the possibility of large adult abundance.	probable

Extent and Occupancy Information

Estimated extent of occurrence	71 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	20 km²
Is the population "severely fragmented" ie. is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	< 5

* See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term

Is there an [observed, inferred, or projected] decline in extent of occurrence?	Yes, inferred based on loss of the host plant Antelope-brush
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes, inferred based on loss of the host plant Antelope-brush
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Yes, inferred based on loss of the host plant Antelope-brush
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Yes, inferred based on loss of the host plant Antelope-brush
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, inferred decline in habitat area and quality.
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
	Unknown
Total	Unknown

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	None.

Threats (actual or imminent, to populations or habitats, from highest impact to least)

The cumulative loss, degradation, and fragmentation of the Antelope-brush ecosystem are the primary threats to Nuttall's Sheep Moth. The ecological integrity and condition of Antelope-brush grasslands have been severely reduced. Threats include fragmentation by

- agricultural development (particularly vineyard),
- urban/suburban development,
- alteration to fire regimes and the resultant high intensity wildfires at some sites,
- overgrazing from domestic livestock,
- spread and continued introduction of invasive non-native plants.

* See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Washington State populations are apparently stable.
Is immigration known or possible?	Unknown. Adults are capable of flight and nearest known Washington population is approximately 100 km from nearest potentially suitable habitat in Canada. However, it is unlikely, because they are habitat-specific, do not feed as adults and not known for long-distance movements.
Would immigrants be adapted to survive in Canada?	Yes. Northern Washington has similar climate and vegetation as the southern Okanagan Valley.
Is there sufficient habitat for immigrants in Canada?	Yes. Apparently suitable habitat appears to be currently unoccupied, including at some historical sites in the Okanagan Valley.
Are conditions deteriorating in Canada?[+]	Yes. Habitat is being lost through conversion to other land use practices such as vineyards and residential development.
Are conditions for the source population deteriorating?[+]	Yes, but land development pressures in northern Washington are less severe than in southern B.C.
Is the Canadian population considered to be a sink?[+]	No. Nuttall's Sheep Moth has persisted in Canada for over 100 years and is assumed self-sustaining because there is no evidence of regular movements of large numbers of individuals from Washington state.
Is rescue from outside populations likely?	Not likely. Adults do not feed and it is unlikely they would expend energy to disperse long distances.

Data Sensitive Species

Is this a data sensitive species? No.

Status History

COSEWIC: Designated Endangered in November 2015.

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Status and Reasons for Designation:

Status:	**Alpha-numeric codes:**
Endangered	B1ab(iii)c(iv)+2ab(iii)c(iv)

Reasons for designation:
This large, showy and conspicuous moth is restricted to Antelope-brush habitat in the Okanagan Valley of British Columbia. That habitat type has declined considerably in quality and extent in the past century and remains under threat due to continued conversion to viticulture, residential and commercial development, and impact of wildfires. This is a rare moth in Canada: very few have been observed since the first record in 1920. Potentially large fluctuations in the population size may affect its long-term viability.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. There are no data to support declines.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered B1ab(iii)c(iv)+2ab(iii)c(iv) since the EOO and IAO are both below the threshold (71 km² and 20 km², respectively); meets sub-criterion “a” since there are fewer than 5 locations; meets sub-criterion “b” since there is a continuing decline in the (iii) area, extent and quality of habitat due to continued development and fragmentation of Antelope-brush ecosystems throughout BC; meets sub-criterion “c(iv)” as populations appear to undergo extreme fluctuations based on observations of large numbers of larvae, and large numbers of pupae that will then diapause within the ground for multiple years, and the possibility of wildfire that could cause all pupae to perish and result in their extirpation at a location.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Population size and rates of decline unknown.
Criterion D (Very Small or Restricted Population): Not applicable. Population numbers unknown.
Criterion E (Quantitative Analysis): Not applicable. No data available.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2015)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

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Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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TABLE OF CONTENTS

List of Figures

List of Tables

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Order: Lepidoptera - butterflies and moths

Superfamily: Bombycoidea

Family: Saturniidae Boisduval, 1837 – wild or giant silk moths

Subfamily: Hemileucinae Walker, 1855 - buck, sheepmoths

Genus: *Hemileuca* Walker, 1855

Species: *Hemileuca nuttalli* (Strecker 1875)

Type locality: Rocky Mountains, head of Snake River.

Taxonomic Background: *Hemileuca* is a diverse genus of silk moths, with 16 of the 20 described species found in western North America (Powell and Opler 2009). Nuttall's Sheep Moth (*Hemileuca nuttalli*) was first described by Strecker in 1875 (Strecker 1872-1877) as *Pseudohazis nuttalli*, and was long confused with the Western or Elegant Sheep Moth (*Hemileuca eglanterina*) (Boisduval 1852), until Ferguson (1971) clearly defined the diagnostic differences between these two species. Under experimental conditions, male Nuttall's Sheep Moths will sometimes mate with female Western Sheep Moths, but no viable embryos are produced (Collins and Tuskes 1979). A colour morph associated with high elevations was described as the subspecies *Hemileuca nuttalli uniformis* (Cockerell 1914) but has been reduced to a synonymy (Tuskes *et al.* 1996).

English Names: Nuttall's Sheepmoth (e.g., Opler *et al.* 2014) or Nuttall's Buck Moth (e.g., Young and Marks 2009). The species was named after Thomas Nuttall, an English zoologist and botanist who collected in western North America in the early 1800s.

French Name: Hémileucin de Nuttall

Morphological Description

Nuttall's Sheep Moth has four developmental stages: egg, larva, pupa and adult.

Adult:

Nuttall's Sheep Moth adults are relatively large (forewing length 32-39 mm for both sexes) moths with white to pale yellow forewings and bright yellow hindwings, thick black transverse lines (medial and post-medial), black veins near the wing margins, black wing edges, and very large discal spots on both wings (Figure 1; Crabo *et al.* 2012). Both sexes have similar maculation and ground colour, although females tend to have more yellow on the dorsal forewing than males, especially distal to the postmedial line (Tuskes *et al.* 1996). The body is yellow and the antennae are bipectinate, much wider in males than in females.

Figure 1. Adult male Nuttall's Sheep Moth (Benton County, WA; Photo Merrill A. Peterson photo, with permission).

Two other species of *Hemileuca* co-occur with Nuttall's Sheep Moth. Western Sheep Moth has pink-suffused forewings and typically has heavier black maculation, although the form "*denuda*" lacks these markings entirely. Nuttall's Sheep Moth is distinguished from Western Sheep Moth by the inwardly concave shape of the black postmedial line on the hindwing between vein M3 and the inner margin of the wing (it is straight or outwardly convex in Western Sheep Moth) (Tuskes *et al.* 1996). Co-occurring Hera or Sagebrush Buck Moth (*H. hera*) adults are white with black markings.

Egg:

Nuttall's Sheep Moth eggs are oval and whitish-grey (Ife pers. comm. 2014).

Larva:

Early larval instars are black with stinging spines (McFarland 1974) and are superficially similar to nymphalid butterfly larvae. However, the uppermost dorsal rows of tubercles (scoli) of *Hemileuca* larvae are shorter than those of the subdorsal rows, and lack the large, conspicuous elongated central shaft found in nymphalids (Ferguson 1971). Late instar larvae of Nuttall's Sheep Moth (Figure 2) are variable in colour (Tuskes *et al.* 1996), and are difficult to distinguish from other co-occurring *Hemileuca* larvae (St. John 2010). In southern B.C., late larval instars lack the longitudinal white line and orange-yellow tufts of dorsal spines that are found on Western Sheep Moth and Hera Buck Moth (Ife pers. comm. 2014; St. John 2010). Final instar Nuttall's Sheep Moth larvae have 6-10 setae on the clypeus compared to only 4 in the other two *Hemileuca* species found in B.C, and there can also be differences in the colour of the ventral abdominal surface and prolegs (Tuskes 1976). Final instar larvae are over 50 mm long with a head capsule width of just under four mm (St. John 2010).

Figure 2. Late instar larva on Nuttall's Sheep Moth on Antelope-brush (*Purshia tridentata*) (Photo Steve Ife, with permission).

Pupa:

The pupa is a dark rusty-brown and about 27-31 mm long (Davis pers. comm. 2015) (Figure 3), with females slightly larger than males (Ife pers. comm. 2015).

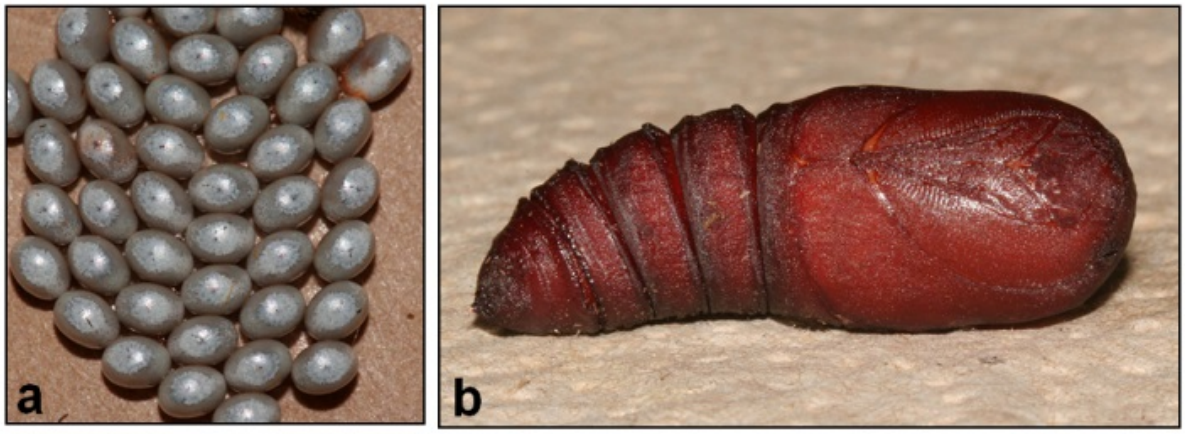

Figure 3. Ova (a) and male pupa (b) of Nuttall's Sheep Moth (Photo Nicky Davis, with permission).

Population Spatial Structure and Variability

Elsewhere in its global range, Nuttall's Sheep Moth has a colour form with less contrast ("uniformis") associated with high elevations, which appears to have a stable genetic basis rather than being environmentally induced (Tuskes *et al.* 1996). No data are available for Canadian populations, which occur at lower elevations and are of the typical coloration. Mitochondrial DNA studies (e.g., Rubinoff and Sperling 2004) have been conducted for other *Hemileuca* species but not for Nuttall's Sheep Moth.

Designatable Units

Nuttall's Sheep Moth is being assessed as one designatable unit. There is no information on discreteness or evolutionary significance among populations, but in Canada the species occurs within a small contiguous area in the COSEWIC Southern Mountain Ecological Area.

Special Significance

Nuttall's Sheep Moth is emblematic of a southern biogeographic element that reaches its northern limit in extreme southern B.C. The Antelope-Brush (*Purshia tridentata*) ecosystem of the arid south Okanagan Valley is one of the four most endangered ecosystems in Canada (Schluter *et al.* 1995) and the area supports approximately 15,000 invertebrate species, including provincially, nationally, and globally rare taxa such as the Behr's Hairstreak (*Satyrium behrii*) which also depends upon Antelope-brush as a larval host plant (COSEWIC 2012; Cannings and Cannings 1995).

Hemileuca moths are a diverse genus and have long been favoured for study by amateur and professional entomologists, in part due to their diurnal habits and striking coloration. Regardless of this widespread interest, the genus remains poorly understood. Numerous researchers work on this genus as it remains a useful model for the study of biogeography, gene flow, and evolution (McElfresh and Millar 2001; Rubinoff and Sperling 2002, 2004).

DISTRIBUTION

Global Range

The global range of Nuttall's Sheep Moth extends from extreme southern British Columbia as far south as California, northern Arizona and New Mexico. Its core range is the dry interior of the Great Basin and Columbia River drainage, from the Cascade Mountains and Sierra Nevada east to the edge of the Rocky Mountains in western Montana, Wyoming, and Colorado (Figure 4).

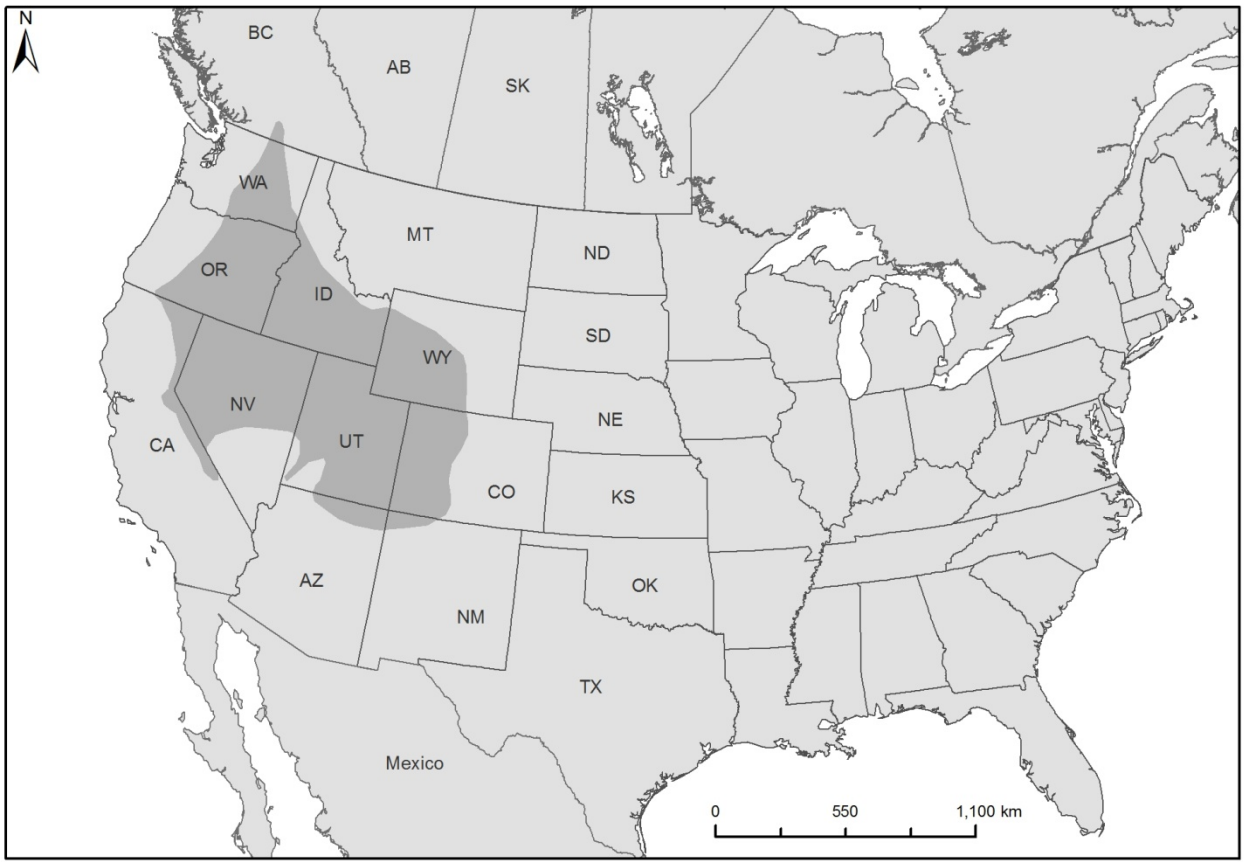

Figure 4. Approximate global range of Nuttall's Sheep Moth. Adapted from Peigler and Opler (1993) and Tuskes *et al.* (1996) using records from Crabo *et al.* (2012) and Opler *et al.* (2014).

Canadian Range

In Canada, Nuttall's Sheep Moth has only been observed from three general areas in the Okanagan Valley within 35 km north of the international border (Table 1, Figure 4). These are: 1) Osoyoos, 2) Oliver (precise site unknown), and 3) Vaseux Lake (two sites approximately 1400 m apart but with suitable intervening habitat). Nuttall's Sheep Moth individuals were observed in 1986 at Haynes' Lease Ecological Reserve approximately 8 km north of Osoyoos; it is not known if this is the same site as the 1920 and 1953 Osoyoos records. Vaseux Lake sites are at approximately 340 m elevation and Haynes' Lease Ecological Reserve is at 350-370 m elevation. Canada has less than 1% of the global range and population and represents the northern limit of its continental range.

Table 1. Documented specimens and sightings of Nuttall's Sheep Moth in Canada.

Location (as per label)	Date	Collector	Coll.	Notes
Oliver	1965-08-30	H. Kimmich	UBC	1F, wild-caught
Oliver	1965-08-30	unlabelled[1]	UBC	1M, wild-caught
Osoyoos	1920-10-09	E.H. Blackmore	UBC	1M, reared from larvae
Osoyoos	1920-10-10	E.H. Blackmore	UBC	1M, reared from larvae
Ozozoos, B.C.	1953-08-25	J.E.H. Martin	CNC	2 adults, wild-caught
Osoyoos, Haynes' Ecol. Res.	1986-08-14	B.A. Macdonald	UBC	1M, wild-caught
Vaseux Lake[2]	1975-05-15	C. Guppy	field obs.	abundant half-grown to mature larvae
Vaseux Lake[2]	1976-05-15	C. Guppy	field obs.	abundant young to half-grown larvae
Vaseux Lake[2]	1987-08-25	C. Guppy	RBCM	1 adult, reared from larvae
Vaseux Lake[2]	1987-09-04	C. Guppy	RBCM	1 adult, reared from larvae
Vaseux Lake[2]	1987-09-05	C. Guppy	RBCM	1 adult, reared from larvae
Vaseux Lake[2]	1988-04-27	C. Guppy	RBCM	27 larvae collected from antelope brush
Vaseux Lake[2]	1988-05-11	C. Guppy	RBCM	7 larvae collected from antelope brush
Vaseux Lake[3]	1988	S. Ife?	RBCM	1 larvae
Vaseux Lake	1995-04-10	M. Jackson	field obs.	1st instar larvae
Vaseux Lake	1994-05-13	M. Jackson	field obs.	3rd/4th instar larvae
Vaseux Lake[3]	1997-05-15	S. Ife	field obs.	4th/5th instar larvae
Vaseux Lake[3]	2002-05-20	S. Ife	field obs.	approximately fifty 4th and 5th instar larvae

[1] Specimen can reasonably be assumed to be collected by Helmut Kimmich, who usually collected alone and donated his collection to the University of British Columbia Entomology collection (C. Guppy pers. comm. 2015).

[2] UTM11, 316100E 5463600N, NAD83

[3] UTM11, 315272E 5464906N, NAD83

The known Canadian range of Nuttall's Sheep Moth is much more restricted than shown in Tuskes *et al.* (1996), which appears to be roughly based on the Canadian range of its larval host plant, Antelope-brush (*Purshia tridentata*). In B.C., Antelope-brush is restricted to two small areas: the lower elevations of the south Okanagan Valley and the Southern Rocky Mountain Trench of the East Kootenays. In the Okanagan, it is locally common and occurs in small, remnant patches of dry, sandy shrublands south of Penticton, although there are one or two small occurrences in the central Okanagan around Kelowna. In the Rocky Mountain Trench, Antelope-brush is restricted to scattered patches of grassland and Ponderosa Pine (*Pinus ponderosa*) woodland north to about Columbia Lake (Klinkenberg 2014; Parish *et al.* 1996; Schluter *et al.* 1995). Despite this wider range of Antelope-brush, Nuttall's Sheep Moth apparently inhabits only the hottest portions of its host's range in Canada.

Five specimens housed in the CNC and collected 1922 – 1956 from Waterton Lakes National Park were erroneously identified as *uniformis* variety of Nuttall's Sheep Moth. These specimens were recently confirmed as Western Sheep Moth (Lonsdale pers. comm. 2014).

Extent of Occurrence and Area of Occupancy

The maximum extent of occurrence (minimum convex polygon) in Canada is 71 km^2 based on the generalized UTMs of known records. The maximum index of area of occupancy (IAO) (2 km x 2 km grid) is 20 km^2 (5 grid squares).

Search Effort

The Okanagan Valley is well-known "hotspot" for rare invertebrates in Canada (Cannings and Cannings 1995). This area has been the focus of numerous Lepidoptera surveys, particularly for Behr's Hairstreak (*Satyrium behrii*), which inhabits the same Antelope-brush habitats (COSEWIC 2012) as Nuttall's Sheepmoth. Unlike most moths, the large and colourful Nuttall's Sheep Moth adults are diurnal, and detected without nocturnal surveys or specialized techniques (e.g., black lights). However, adults do not feed and can be difficult to identify on the wing or catch due to their rapid, erratic flight patterns (Tuskes *et al.* 1996). *Hemileuca* larvae are gregarious when young, and although large and distinctive as later instars, species determination can be problematic (St. John 2010). Both Nuttall's and Western sheep moths can be found at Vaseux Lake, although the former appears to reach final instar 2-3 weeks earlier than Western Sheep Moth (Ife pers. comm. 2014; St. John 2010).

To date, search effort in potential habitat is by wandering transect, searching for flying adults or larvae on Antelope-brush host plants. This is considered an efficient method for surveying diurnal Lepidoptera where distribution is poorly known and expected abundance is low (Haddad *et al.* 2008; Hamm 2013). The use of reared, virgin *Hemileuca* females to attract males is an effective method to survey large areas and find new populations (Tuskes *et al.* 1996). To date, this technique has not yet been successful at confirming the presence of this Nuttall's Sheep Moth in B.C. It is difficult to obtain female larvae and rear these to adults (Ife pers. comm. 2014).

There are fewer than 20 documented observations of Nuttall's Sheepmoth since it was first recorded at Osoyoos in 1920 (Table 1).

Null search effort is summarized in Table 2. Recent search effort includes:

- In 2009, six sites in Antelope-brush habitats in the southern Okanagan from August 24 to September 1, 2009. Approximately 24 person-hours and 26 km of wandering transect (Young and Marks 2009). Six adult Hera Buck Moths (*Hemileuca hera*) were recorded in about 40 min search effort in sagebrush-steppe at White Lake on August 26, 2009 (St. John pers. comm. as cited in Young and Marks 2009), suggesting that the timing of the survey was appropriate.
- In 2014, over 6200 Antelope-brush plants at 18 sites in the Okanagan Valley were examined for Nuttall's Sheep Moth larvae from May 26-29 during 30 person-hours and 30 km of wandering transects (Table 2). Survey timing was appropriate given the presence of approximately 35 Western Sheep Moth larvae (likely 4th instar based on size and date) found on Common Snowberry (*Symphoricapo*s *albus*) and Wood's Rose (*Rosa woodsii*) at one site near Vaseux Lake. No Nuttall's Sheep Moth larvae were observed during these surveys.

Table 2. Summary of recent, unsuccessful, targeted surveys for larval (2014) and adult surveys (2009) for Nuttall's Sheep Moth in Canada.

Site Name	Approx. Easting	Approx. Northing	Obs.[1]	Date Surveyed	Survey Time (person-hours)	Survey Length (km)	# *Purshia* Checked
Blue Mountain Property - TNT	315475	5466972	VY, DM	2009-08-28	3.0	3.6	-
Fairview	310898	5449866	VY, DM	2009-08-24	3.3	4.2	-
Haynes' Lease Ecol. Reserve	315989	5440420	VY, DM	2009-08-31	8.0	9.2	-
Kennedy Property - TNT	316464	5459043	VY, DM	2009-08-24	3.2	4.0	-
SOMA North	313407	5443846	VY, DM	2009-09-01	1.8	1.3	-
SOMA South	314637	5441442	VY, DM	2009-09-01	4.7	4.0	-
Fairview	310743	5449944	RF, BR	2014-05-28	1.7	2.5	407

Site Name	Approx. Easting	Approx. Northing	Obs.[1]	Date Surveyed	Survey Time (person-hours)	Survey Length (km)	# *Purshia* Checked
Haynes' Lease Ecol. Reserve	315728	5441013	RF, BR	2014-05-26	2.1	1.8	105
Haynes' Lease Ecol. Reserve	315925	5440743	RF, BR	2014-05-29	2.3	4.0	556
Hwy 3 East of Osoyoos	323812	5432411	RF, BR	2014-05-29	1.3	1.7	180
Nk'mip Desert Cultural Centre	322162	5435300	RF, BR	2014-05-29	1.4	4.1	161
Okanagan Falls - Allendale Road	314942	5466806	RF, BR	2014-05-28	2	2.3	563
Okanagan Falls - Antelope Brush CA	316355	5459127	RF, BR	2014-05-27	2	3.0	541
Okanagan Falls - Shuttleworth Cr. E	316642	5467215	RF, BR	2014-05-28	2.1	2.4	462
Okanagan Falls - Shuttleworth Cr. W	315975	5467244	RF, BR	2014-05-28	4.4	4.3	971
Oliver - near Covert Farms	314057	5457253	RF, BR	2014-05-27	2.1	2.1	597
Osoyoos Desert Centre	316189	5436314	RF, BR	2014-05-27	1.4	1.7	388
Osoyoos Bench	317936	5434011	RF, BR	2014-05-29	2	1.7	516
Testalinden	310949	5445203	RF, BR	2014-05-29	0.3	0.4	90
Vaseux Lake McIntyre Creek Road	317468	5462302	RF, BR	2014-05-27	0.8	0.5	99
Vaseux Lake North	315468	5464872	RF, BR	2014-05-26	1.9	1.8	191
Vaseux Lake South - main	316383	5462990	RF, BR	2014-05-27	1.4	0.9	116
Vaseux Lake South - ridge	316405	5463269	RF, BR	2014-05-27	0.6	0.6	45
White Lake Grasslands	312880	5456688	RF, BR	2014-05-27	1	0.9	240

[1] Observers: VY=Vince Young; DM=Dawn Marks; RF=Rob Foster; BR=Brian Ratcliff

Table 3. Known and generalized Nuttall's Sheep Moth sites and threats.

Site Name	Vaseux Lake (2 sites 1.6 km apart)	Osoyoos, Haynes' Ecol. Res.	Oliver, exact location unknown	Osoyoos/Ozozoos, exact location unknown	Threats Tally (number of sites)
Yr First Recorded	1975	1920?	1965	1920?	
Yr Last Recorded	2002	1986	1965	1953	
Yr Last Surveyed	2014	2014	?	?	

Site Name	Vaseux Lake (2 sites 1.6 km apart)	Osoyoos, Haynes' Ecol. Res.	Oliver, exact location unknown	Osoyoos/Ozozoos, exact location unknown	Threats Tally (number of sites)
Land Ownership	Protected / private conservation land (The Nature Trust)	Protected (BC Parks; provincial Crown); and adjacent Wildlife Management Area (provincial Crown).	?	?	
Search Effort Notes	Numerous sites have been surveyed in 2009 and 2014; as well as by independent entomologists	Nuttall's Sheepmoth only found on Haynes' Ecol. Res., although adjacent Wildlife Management Area also has Antelope-brush and moth likely uses this habitat.			
1.1 Housing & urban areas	Intervening private lands could be developed.	Adjacent private lands could be developed; housing development growing on property within 1km.	Undesignated provincial crown land with Antelope-brush - pressure from Town of Oliver to purchase for urban expansion.	The Town of Osoyoos would like to purchase part/all of a large parcel of provincial crown land with some Antelope-brush (approx 300ha) for town expansion.	4
1.2 Commercial & industrial areas		Adjacent private lands could be developed	Less than residential, but ongoing. E.g., prison, industrial park expansion (however, few buildings).		4
1.3 Tourism & recreation areas		Adjacent private lands could be developed	Not substantial.		4
2.1 Annual & perennial non-timber crops	Private lands suitable for vineyard development.	Adjacent private lands have been developed for vineyards; other adjacent properties with high potential for agricultural conversion.	Private lands suitable for vineyard development.	Private lands suitable for vineyard development.	4
2.2 Wood and pulp plantations	N/A	N/A	N/A	N/A	
2.3 Livestock farming & ranching	Adjacent private lands currently have ranching	Some adjacent lands currently have ranching; Wildlife Management Area adjacent to Haynes' Lease is grazed and Nuttall's Sheepmoth likely uses this habitat too.	Unknown; some Antelope-brush habitats are grazed.	Unknown; some Antelope-brush habitats are grazed.	At least 2

Site Name	Vaseux Lake (2 sites 1.6 km apart)	Osoyoos, Haynes' Ecol. Res.	Oliver, exact location unknown	Osoyoos/Ozozoos, exact location unknown	Threats Tally (number of sites)
2.4 Marine & freshwater aquaculture	N/A	N/A	N/A	N/A	N/A
3.1 Oil and Gas drilling	N/A	N/A	N/A	N/A	N/A
3.2 Mining and quarrying	Private lands have previously had aggregate pits	Potential on adjacent lands	Unknown.	Unknown.	At least 2
3.3 Renewable energy	NA	NA	NA	NA	
4.1 Roads and railroads	Potential on adjacent lands	Potential on adjacent lands	Potential	Potential	Unknown
4.2 Utility & service lines	Potential on adjacent lands	Potential on adjacent lands	Potential	Potential	Unknown
4.3 Shipping lanes	N/A	N/A	N/A	N/A	N/A
4.4 Flight paths	N/A	N/A	N/A	N/A	N/A
5.1 hunting & collecting	N/A	N/A	N/A	N/A	N/A
5.2 Gathering terrestrial plants	N/A	N/A	N/A	N/A	N/A
5.3 Logging & wood harvesting	N/A	N/A	N/A	N/A	N/A
5.4 Fishing	N/A	N/A	N/A	N/A	N/A
6.1 Recreational activities	minor potential from ATV use on private lands	minor potential from ATV use on adjacent private lands	minor potential from ATV use on private lands	minor potential from ATV use on private lands	Not significant, although in unchecked habitats.
6.2 War...	N/A	N/A	N/A	N/A	N/A
6.3 Work & other activities	N/A	N/A	N/A	N/A	N/A
7.1 Fire and Fire suppression	fire and fire suppression has occurred recently	fire and fire suppression a risk	fire and fire suppression a risk	fire and fire suppression a risk	
7.2 Dams and water management	N/A	N/A	N/A	N/A	N/A
7.3 Other ecosystem modifications	N/A	N/A	N/A	N/A	N/A
8.1 Invasive non-natives	potential but impact unknown on species or host plant	potential but impact unknown on species or host plant	potential but impact unknown on species or host plant	potential but impact unknown on species or host plant	unknown threat
8.2 Problematic native species	none known	none known	none known	none known	low threat
8.3 Introduced genetic material	N/A	N/A	N/A	N/A	N/A

Site Name	Vaseux Lake (2 sites 1.6 km apart)	Osoyoos, Haynes' Ecol. Res.	Oliver, exact location unknown	Osoyoos/Ozozoos, exact location unknown	Threats Tally (number of sites)
9.1 Household sewage & urban waste water	N/A	N/A	N/A	N/A	N/A
9.2 Industrial & military effluents	N/A	N/A	N/A	N/A	N/A
9.3 Agricultural & forestry effluents	potential agrochemical drift but impact, if any, unknown	potential agrochemical drift from adjacent vineyards; impact unknown. Overspray of irrigation systems has changed the vegetation adjacent to the site.	potential agrochemical drift but impact, if any, unknown	potential agrochemical drift but impact, if any, unknown	4
9.4 Garbage & solid waste	N/A	N/A	N/A	N/A	N/A
9.5 Air-borne pollutants	N/A	N/A	N/A	N/A	N/A
9.6 Excess energy	N/A	N/A	N/A	N/A	N/A
10.1 Volcanoes	N/A	N/A	N/A	N/A	N/A
10.2 Earthquakes, tsunamis	N/A	N/A	N/A	N/A	N/A
10.3 Avalanches & landslides	N/A	N/A	N/A	N/A	N/A
11.1 Habitat shifting & alteration	potential but impact unknown on species or host plant	potential but impact unknown on species or host plant	potential but impact unknown on species or host plant	potential but impact unknown on species or host plant	4
11.2 Droughts	potential but impact unknown on species or host plant	potential but impact unknown on species or host plant	potential but impact unknown on species or host plant	potential but impact unknown on species or host plant	4
11.3 Temperature extremes	N/A	N/A	N/A	N/A	N/A
11.4 Storms and Flooding	N/A	N/A	N/A	N/A	N/A

There are some areas of the Okanagan that have not been searched for the moth. Approximately 8800 ha of mapped Antelope-brush habitat on the east side of the Okanagan Valley between Okanagan Falls and Osoyoos governed by local First Nations has not been searched (Figure 5). There are some potentially suitable habitats on private land within the species' range, but many of the higher quality Antelope-brush habitats have had past surveys. No targeted surveys for Nuttall's Sheep Moth have been documented for the Kootenay region, although they have been recommended (St. John 2010).

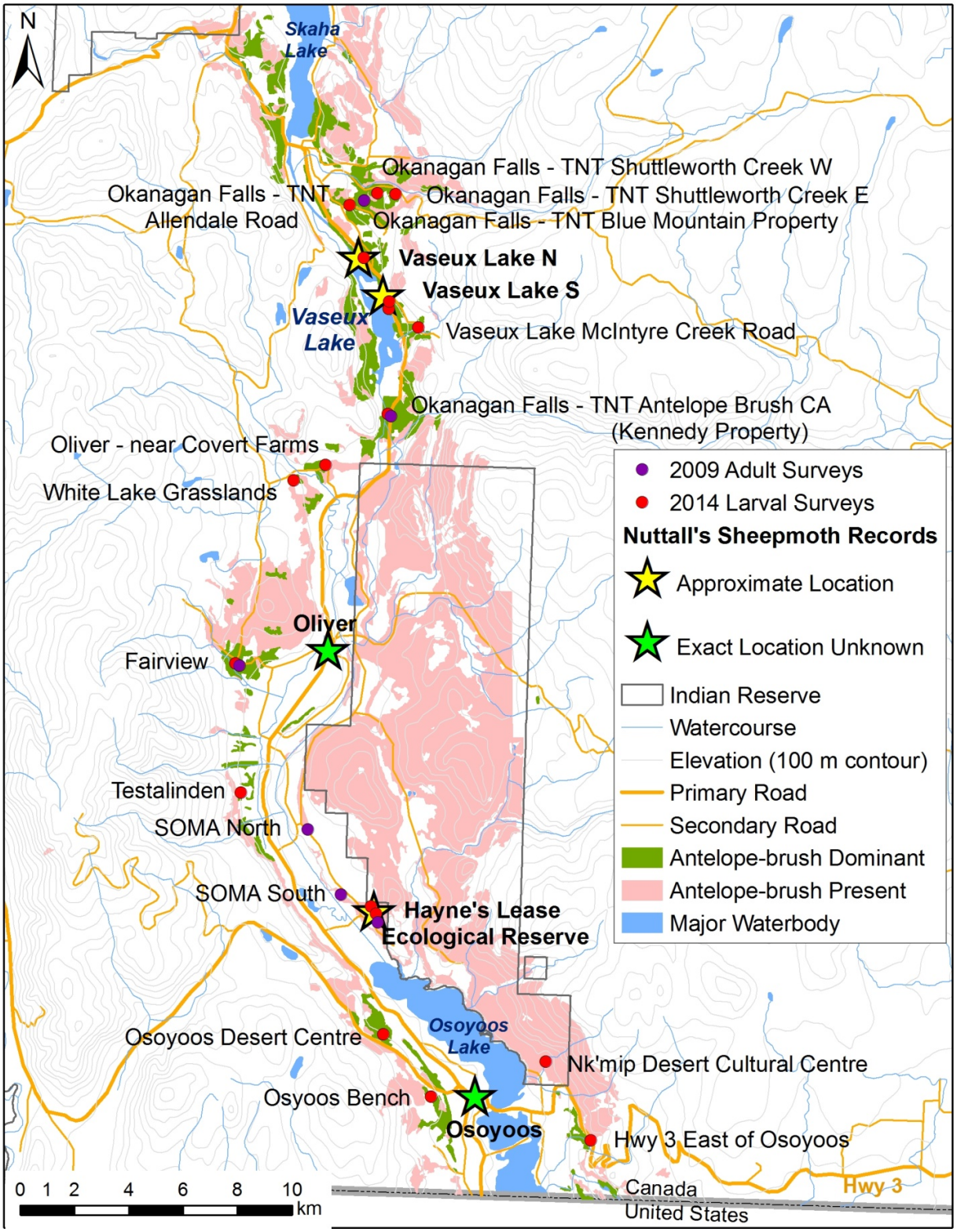

Figure 5. Distribution of Nuttall's Sheep Moth in Canada in relation to Antelope-brush (*Purshia tridentata*) habitat in the Okanagan Valley.

HABITAT

Habitat Requirements

All known Canadian records for Nuttall's Sheep Moth are within the Antelope-brush/Needle-and-Thread Grass (*Purshia tridentata* / *Hesperostipa comata*) community in the hotter, lower parts of the Antelope-brush distribution within the Okanagan (St. John 2010; Lea *et al.* 2004) (Figures 5 & 6). In Canada, Nuttall's Sheep Moth has only been recorded feeding on Antelope-brush (St. John 2010), but elsewhere it has also been recorded on other shrubs, including snowberries (*Symphoricarpos* spp.) (see Life Cycle and Reproduction). Antelope-brush has a small occurrence within the east Kootenays.

In the United States, adults are always associated with sagebrush scrub and pinyon-juniper woodland habitats at lower elevations and with sagebrush meadows at higher elevations (Tuskes *et al.* 1996). However, at the northern edge of its global range in Canada, Nuttall's Sheep Moth appears to be found only in the hotter areas of Antelope-brush dominated habitat.

Figure 6. Nuttall's Sheep Moth habitat with Antelope-brush at Haynes' Lease Ecological Reserve near Osoyoos, looking southeast. Photo by Rob Foster, May 26, 2014.

Habitat Trends

The Antelope-brush/Needle-and-Thread Grass plant community has significantly declined in both quantity and quality since 1800 (Lea 2001, 2008; Schluter *et al.* 1995). Spatial mapping of Antelope-brush habitats shows a reduction of 9800 ha in 1800 to about 3200 ha in 2008; or approximately 1/3 of its original extent (Iverson 2012). Within B.C, none of the remaining Antelope-brush/Needle-and-Thread Grass community is considered to have excellent ecological integrity, with 54% assessed as having good ecological integrity and 46% having fair or poor ecological integrity (Iverson 2012). Antelope-brush has only been mapped for the southern Okanagan Valley (Woods pers. comm. 2014), with limited potential habitat in the north Okanagan and the Kootenay areas.

Historically, Antelope-brush habitats experienced frequent, low intensity fires (Lea 1996; Lea *et al.* 2004), but recent high-intensity fires likely have a greater risk to local populations of Nuttall's Sheep Moth (see Threats). During the mid-2000s, there were extensive fires within the Okanagan Valley, and Antelope-brush habitats were significantly impacted from these fires (Dyer pers. comm. 2015). A human-caused fire burned previously occupied habitat for Nuttall's Sheep Moth in 2003 near Vaseux Lake on Nature Trust of B.C. property, destroying much of the Antelope-brush there (Figure 7).

Figure 7. Fire-killed Antelope-brush at previously documented Nuttall's Sheep Moth habitat east of Vaseux Lake, May 27, 2014 (looking north). Photo by Rob Foster, May 26, 2014.

BIOLOGY

Life Cycle and Reproduction

Nuttall's Sheep Moth typically have a one year life cycle, but may need two years to complete development at high elevations and northern latitudes (Opler *et al.* 2014). This life cycle has been reported for Western Sheep Moth (Evans 1958). Females lay 50-200 eggs in rings around host plant stems in late summer, which then overwinter. Larvae hatch in May to early June (Tuskes *et al.* 1996), but 1st instar caterpillars have been found near Vaseux Lake, B.C. as early as April 10 (Table 1). Larvae are gregarious when young but disperse as 3rd or 4th instars to feed alone. There are five instars and fully-grown caterpillars pupate in loose cocoons in leaf litter or burrows in soft soil (Tuskes *et al.* 1996; Davis 2014). Adults emerge later that season, or possibly the following year (St. John 2010).

In B.C., early instars have only been observed feeding on Antelope-brush (Guppy pers. comm. 2014), but elsewhere in their range larvae have also been reported on snowberry (*Symphoricarpos* spp.) (Opler *et al.* 2014), Desert Sweet (*Chamaebatiaria millefolium*), and currants (*Ribes* spp.) (Tuskes *et al.* 1996). Larvae have been reared on Common Snowberry (*S. albus*), Roundleaf Snowberry (*S. rotundifolius*), Douglas' Meadowsweet (*Spiraea douglasii*), and Birchleaf Mountain Mahogany (*Cercocarpus betuloides*) (Davis 2014; S. Ife pers. comm. 2014; Tuskes 1984; McFarland, 1974). Currant and snowberry occur in Antelope-brush habitats within the range of Nuttall's Sheep Moth in British Columbia, and could potentially serve as larval host plants.

Adults have been observed in the Okanagan Valley from August 14-30, which falls within the expected flight period based on approximately 40 records from elsewhere in the northern parts of its range in the United States (Figure 8). In the southern parts of its range in the United States the flight season is from July to early September, with a peak in early August, and earlier at high elevations (Tuskes *et al.* 1996). Two adults reared from larvae by Blackmore in 1920 did not emerge until October 9-10 (Table 1).

As with other *Hemileuca*, adult Nuttall's Sheep Moths do not feed and have a short life span of several days (Tuskes *et al.* 1996). Both sexes are active daytime fliers and their brief flight period is devoted to reproduction (Collins and Tuskes 1979). Adults emerge in the morning but mating does not occur until early afternoon. Collins and Tuskes (1979) showed that in California, peak flight of adults occurs from 13:30 to 16:30, just after the peak flight of sympatric Western Sheep Moths. Females emit pheromones that flying males use to locate potential mates, and diurnal activity patterns contribute to reproductive isolation among species.

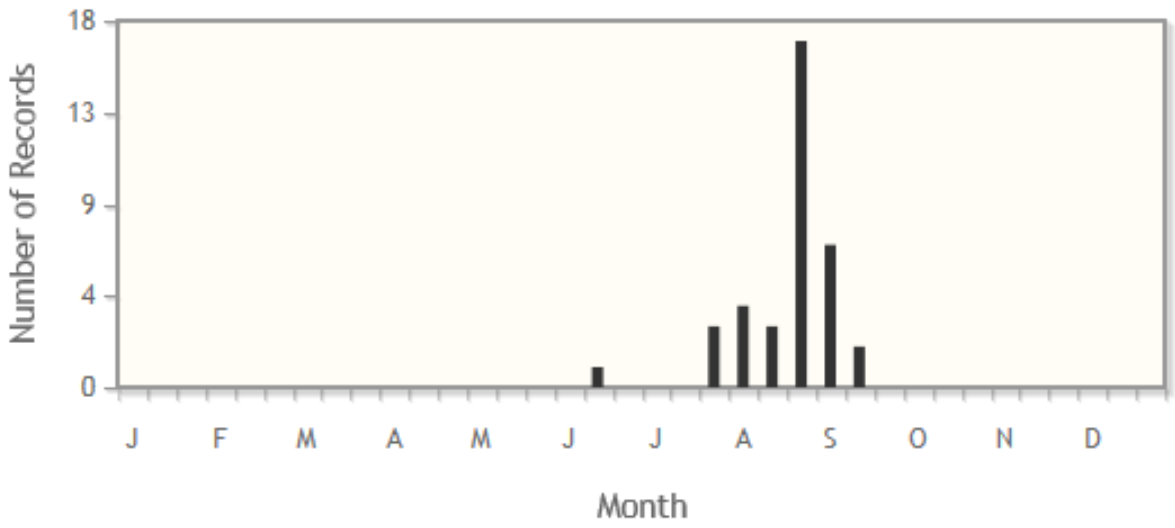

Figure 8. Seasonality of adult flight season for Nuttall's Sheep Moth in the Pacific Northwest (Crabo *et al.* 2012).

Physiology and Adaptability

Nuttall's Sheep Moth has some physiological and ecological adaptability, with known larval host plants from several different plant families. Of these, Antelope-brush is known to produce a variety of secondary compounds including the cyanoglucosides purshianin and menisdaurin (Nakanishi *et al.* 1994), but it is not known how this may affect the physiology and ecology of Nuttall's Sheep Moth.

Throughout its range, Nuttall's Sheep Moth occurs from low elevation to over 2500 m altitude and has a north-south range of approximately 1500 km. Daily sunlight is necessary for larvae to feed and grow, and adults tend to fly mainly in sunny weather (MacFarland 1974; Powell and Opler 2009).

Dispersal and Migration

No studies have reported dispersal distances for Nuttall's Sheep Moth. However the related Nevada Buck Moth (*H. nevadensis*) readily flies for short distances over highly unsuitable environments. Dispersal of up to at least 4 km has been documented for New England Buck Moth (*H. lucina*) (NatureServe 2014).

Interspecific Interactions

Many vertebrate predators that typically consume caterpillars may avoid Nuttall's Sheep Moth due to the venomous spines. However, adults may fall prey to insectivorous birds and spiders (Aranaeidae). Ants (Formicidae) and beetles (Coleoptera) have been observed preying upon the larvae or pupae of other *Hemileuca* species (COSEWIC 2009; Pryor 1998). The parasitoids *Enicospilus americanus* (Hymenoptera: Ichneumonidae) and *Cotesia* sp. (Hymenoptera: Braconidae) are known to attack Nuttall's Sheep Moth larvae (Collins 1974). At times more than 90% of mature *Hemileuca* larvae can be parasitized, although 1st and 2nd instar larvae are usually free of parasitoids (Tuskes *et al.* 1996).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Surveys for Nuttall's Sheep Moth have focused on recording the species presence within a habitat. See *Survey Effort.*

Abundance

Populations at historical sites, if any, are likely small. Surveys in 2009 and 2014, and lack of other recent records support this inference. In 1975-76, Nuttall's Sheep Moth larvae "likely totalled in the many thousands" at the site east of Vaseux Lake with "larvae in sight at almost all times along a 500 m survey transect (C. Guppy pers. comm. 2014). Approximately 50 larvae were last observed at the Vaseux Lake "north" site May 20, 2002, and were abundant in previous years (Ife pers. comm. 2014). However, after a wildfire at the Vaseux Lake site in 2004, no caterpillars or sign of feeding were observed on May 15, 2011 (Ife pers. comm. 2014), nor in 2014 (Foster pers. comm. 2014; Ratcliff pers. comm. 2014).

Fluctuations and Trends

There is no information on Canadian or global population trends. No Nuttall's Sheep Moths were observed at Haynes' Lease Ecological Reserve or Vaseux Lake sites in 2014. However, due to low detectability and short adult life span, these populations are presumed extant. It is unknown if the older specimens for "Osoyoos" (1920) and "Ozozoos" (1953) are from what is now Haynes' Lease Ecological Reserve, or from somewhere else in the Osoyoos area. The precise location and fate of the 1965 "Oliver" population are unknown but it is possibly extirpated (or may be the same site as Vaseux Lake).

Nuttall's Sheep Moth likely experiences extreme fluctuations in abundance. The abundant larval observations in 1975-76, and again in 2002 (see Abundance), suggest the possibility of extreme fluctuations in adult moths. In order to produce large numbers of larvae, large numbers of eggs would have overwintered on the host plant stems. Larvae hatch in the spring and begin feeding and presumably, many of these larvae would fall to the soil to pupate. Some of these pupae may remain dormant for more than one season. A threatening event, such as a wildfire, could decimate a population of the moths at the egg stage or larval stage (e.g., brush fire that kills Antelope-brush), or during the pupal stage (e.g., ground or surface fire) if it were to occur during one of these large population events. Other sheep moth populations are known to experience extreme fluctuations in abundance (Schmidt pers. comm. 2015).

Rescue Effect

Given their strong flying ability, Nuttall's Sheep Moths could potentially immigrate from northern Washington State or Idaho. They have been confirmed from Brewster, WA (Crabo *et al.* 2012) approximately 100 km south of Osoyoos, and there appears to be suitable intervening habitat (LaBar pers. comm. 2015; Swedberg pers. comm. 2015) and potentially undetected populations along the intervening Okanagan Valley.

THREATS AND LIMITING FACTORS

The International Union for Conservation of Nature-Conservation Measures Partnership (2006) (IUCN-CMP) threats calculator was used to classify and list threats to the Nuttall's Sheep Moth (Salafsky *et al.* 2008; Master *et al.* 2009). The results of the threats calculator were High – Medium. These threats are listed from highest to lowest.

The cumulative loss, degradation, and fragmentation of the Antelope-brush ecosystem are the primary threats to Nuttall's Sheep Moth (Figure 9). The ecological integrity and condition of Antelope-brush grasslands have been severely reduced: fragmentation by agricultural (particularly vineyard) and urban/suburban development, alteration to fire regimes, overgrazing from domestic livestock, and the spread and continued introduction of invasive alien plants (Iverson 2012). These factors continue to threaten the remaining occurrences of this ecological community (Iverson 2012).

Table 4. IUCN Threats Calculator results for Nuttall's Sheep Moth (*Hemileuca nuttalli*) in Canada.

The classification below is based on the IUCN-CMP (World Conservation Union–Conservation Measures Partnership) unified threats classification system. For a detailed description of the threat classification system, see the CMP website (CMP 2010). Threats may be observed, inferred, or projected to occur in the near term. Threats are characterized here in terms of scope, severity, and timing. Threat "impact" is calculated from scope and severity. For information on how the values are assigned, see Master *et al.* (2009) and table footnotes for details.

Nuttall's Sheep Moth (*Hemileuca nuttalli*)			
Date: January 5, 2015			
Assessed by: Rob Foster (Northern Bioscience; report co-writer), Orville Dyer (BC Ministry of Forests, Lands and Natural Resource Operations, Penticton); Jenny Heron (COSEWIC Arthropods Co-chair); Dave Fraser (BC); Christian Schmidt (Arthropods SSC).			
		Level 1 Threat Impact Counts	
Threat Impact		**high range**	**low range**
A	Very High	0	0
B	High	2	0
C	Medium	0	2
D	Low	1	1
Calculated Overall Threat Impact:		Very High	Medium

Threat		**Impact[1] (calculated)**		**Scope[2] (next 10 Yrs)**	**Severity[3] (10 Yrs or 3 Gen.)**	**Timing[4]**	**Comments[5]**
1	Residential & commercial development	BC	High - Medium	Large - Restricted (11-70%)	Extreme (71-100%)	High	A primary threat due to human growth and increasing land development in Okanagan, particularly valley bottom antelope-brush ecosystems
1.1	Housing & urban areas	BC	High - Medium	Large - Restricted (11-70%)	Extreme (71-100%)	High	Possible at 3 sites, particularly in Osoyoos and Oliver areas, but many sites in protected areas or land trusts
1.2	Commercial & industrial areas	C	Medium	Restricted (11-30%)	Extreme (71-100%)	High	Penticton and Osoyoos areas primarily, and potentially at undocumented sites
1.3	Tourism & recreation areas	D	Low	Small (1-10%)	Extreme (71-100%)	High	Mainly for golf courses and resort development, such as has already occurred on First Nation land
2	Agriculture & aquaculture	BC	High - Medium	Large - Restricted (11-70%)	Extreme (71-100%)	High	
2.1	Annual & perennial non-timber crops	BC	High - Medium	Large - Restricted (11-70%)	Extreme (71-100%)	High	Vineyard development and expansion are a major threat to Antelope-brush habitats on which Nuttall's Sheep Moth are dependent.
2.2	Wood & pulp plantations		NA				not applicable
2.3	Livestock farming & ranching		Negligible	Pervasive (71-100%)	Negligible (<1%)	High	Widespread livestock grazing but negligible impacts on host plant or unpalatable larvae except perhaps at very high livestock densities or drought
2.4	Marine & freshwater aquaculture		NA				Not applicable
3	Energy production & mining		Negligible	Negligible (<1%)	Serious (31-70%)	High	
3.1	Oil & gas drilling		NA				Not applicable

Threat		Impact[1] (calculated)		Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs or 3 Gen.)	Timing[4]	Comments[5]
3.2	Mining & quarrying		Negligible	Negligible (<1%)	Serious (31-70%)	High	Gravel extraction a localized threat for habitat loss
3.3	Renewable energy		NA				Not applicable
4	Transportation & service corridors		Negligible	Negligible (<1%)	Extreme (71-100%)	High	
4.1	Roads & railroads		Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate	Road expansion in Okanagan has some limited potential for destruction and fragmentation of habitat
4.2	Utility & service lines		Negligible	Negligible (<1%)	Slight (1-10%)	Moderate	Limited disturbance during construction of power lines but antelope brush can persist in rights-of-way
4.3	Shipping lanes		NA				Not applicable
4.4	Flight paths		NA				Not applicable
5	Biological resource use		NA				
5.1	Hunting & collecting terrestrial animals		NA				Not applicable - not easily found and difficult to catch
5.2	Gathering terrestrial plants		NA				Not applicable
5.3	Logging & wood harvesting		NA				Not applicable
5.4	Fishing & harvesting aquatic resources		NA				Not applicable
6	Human intrusions & disturbance		Negligible	Negligible (<1%)	Serious (31-70%)	High	Recreationalists unlikely to disturb stinging caterpillars and adults are swift flyers
6.1	Recreational activities		Negligible	Negligible (<1%)	Serious (31-70%)	High	All-terrain vehicle use may have a local effect on habitat but is not permitted at known extant sites
6.2	War, civil unrest & military exercises		NA				Not applicable
6.3	Work & other activities		NA				Not applicable
7	Natural system modifications	D	Low	Small (1-10%)	Extreme (71-100%)	Moderate	
7.1	Fire & fire suppression	D	Low	Small (1-10%)	Extreme (71-100%)	Moderate	Wildfires can result in the loss of antelope-brush habitats, although are typically fairly localized due to fire suppression. Effects of antelope-brush ecosystems due to fire suppression less clear and unlikely to be felt in next 10 years.
7.2	Dams & water management/use		NA				Not applicable
7.3	Other ecosystem modifications		NA				Not applicable

Threat		Impact[1] (calculated)		Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs or 3 Gen.)	Timing[4]	Comments[5]
8	Invasive & other problematic species & genes		Negligible	Pervasive (71-100%)	Negligible (<1%)	High	The impacts from invasive plants are not likely to impact pupation sites or sandy substrates available to the moth, at the base of the plant. Nectar sources are not an issue because they don't feed as adults.
8.1	Invasive non-native/alien species		Negligible	Pervasive (71-100%)	Negligible (<1%)	High	No known invasive plant that is currently threatening antelope brush. Potential impacts from introduced tachinid fly (*Compsilura concinnata*)
8.2	Problematic native species		NA				Not applicable
8.3	Introduced genetic material		NA				Not applicable
9	Pollution		Unknown	Small (1-10%)	Unknown	High	
9.1	Household sewage & urban waste water		NA				Not applicable
9.2	Industrial & military effluents		NA				Not applicable
9.3	Agricultural & forestry effluents		Unknown	Small (1-10%)	Unknown	High	Drift of herbicides and pesticides from agricultural fields (e.g., vineyards) adjacent to occupied habitat is a threat to host plant and Nuttall's Sheep Moth
9.4	Garbage & solid waste		NA				Not applicable
9.5	Air-borne pollutants		NA				Not applicable
9.6	Excess energy		NA				Not applicable
10	Geological events		NA				
10.1	Volcanoes		NA				Not applicable
10.2	Earthquakes/tsunamis		NA				Not applicable
10.3	Avalanches/landslides		NA				There have been a few landslides in the past ten years but this has not impacted substantial Antelope-brush habitat and this is considered negligible within the next ten years.
11	Climate change & severe weather		Unknown	Pervasive (71-100%)	Unknown	High	Climate suitability for antelope-brush grasslands in Canada could potentially increase as a result of climate change, but an increase in severe weather events could negatively impact populations of Nuttall's Sheep Moth
11.1	Habitat shifting & alteration		Unknown	Pervasive (71-100%)	Unknown	High	Some ecological changes may benefit this species

Threat		Impact[1] (calculated)		Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs or 3 Gen.)	Timing[4]	Comments[5]
11.2	Droughts		Unknown	Pervasive (71-100%)	Unknown	High	An increase in the frequency and intensity of summer drought could result in premature senescence of larval host plants, or may change rain patterns during the larval period, potentially reducing juvenile survival.
11.3	Temperature extremes						Not applicable
11.4	Storms & flooding		Unknown	Pervasive (71-100%)	Unknown	High	Small, isolated populations of Nuttall's Sheep Moth are likely vulnerable to stochastic events and could be threatened by hailstorms or severe frost, particularly if the frequency and intensity of severe weather events increases due to climate change.

[1]**Impact** – The degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened in the area of interest. The impact of each stress is based on Severity and Scope rating and considers only present and future threats. Threat impact reflects a reduction of a species population or decline/degradation of the area of an ecosystem. The median rate of population reduction or area decline for each combination of scope and severity corresponds to the following classes of threat impact: very high (75% declines), high (40%), medium (15%), and low (3%). Unknown: used when impact cannot be determined (e.g., if values for either scope or severity is unknown).

[2]**Scope** – Proportion of the species that can reasonably be expected to be affected by the threat within 10 years. Usually measured as a proportion of the species' population in the area of interest. (Pervasive = 71–100%; Large = 31–70%; Restricted = 11–30%; Small = 1–10%)

[3]**Severity** – Within the scope, the level of damage to the species from the threat that can reasonably be expected to be affected by the threat within a 10-year or three-generation timeframe. Usually measured as the degree of reduction of the species' population (Extreme = 71–100%; Serious = 31–70%; Moderate = 11–30%; Slight = 1–10%).

[4]**Timing** – High = continuing; Moderate = only in the future (could happen in the short term [< 10 years or 3 generations]) or now suspended (could come back in the short term); Low = only in the future (could happen in the long term) or now suspended (could come back in the long term); Insignificant/Negligible = only in the past and unlikely to return, or no direct effect but limiting.

[5]**Comments** – see main body of text (Threats and Limiting Factors) for details

Agriculture and Aquaculture (high – medium impact) (2)

Annual and perennial non-timber crops (2.1)

Vineyard development and expansion are a major threat to Antelope-brush habitats (Iverson 2012). The Antelope-Brush / Needle-and-Thread Grass plant community is rapidly being converted to vineyards because the ecological community is considered an indicator for high grape crop production and is targeted by the wine industry for development (Dyer pers. comm. 2014; COSEWIC 2012). Much of the remaining Antelope-brush habitat near Vaseux Lake, Osoyoos and Oliver is suitable for vineyards, orchards, or other agricultural development. Historically, the conversion of habitat to vineyards and other agricultural use (see Habitat Trends) has likely been a contributing factor to the fragmentation of Nuttall's Sheep Moth populations.

Livestock farming and ranching (2.3)

Livestock grazing occurs at a number of sites, although the intensity or frequency is unknown. When alternate forage is limited (e.g., during drought), cattle grazing on Antelope-brush could result in increased mortality or reduced fitness of Nuttall's Sheep Moths. Browsing of Antelope-brush may reduce food availability for larvae, and livestock could inadvertently ingest eggs or trample pupae.

Residential or Commercial Development (very high – medium impact) (1)

Housing and urban areas (1.1); Commercial and industrial areas (1.2) and *Tourism and recreation areas (1.3)* are all considered primary threats to the Canadian populations of Nuttall's Sheep Moth due to human population growth and increasing land development in the Okanagan. Antelope-brush ecosystems are within the valley bottom of the Okanagan valley, areas with the highest probability of development. The population of the Okanagan itself has tripled every 30 to 40 years since 1940 (Jensen and Epp 2002) and is projected to experience significant growth over the next two decades (Hobson and Associates 2006). Coincident with this growth is the loss, degradation, and fragmentation of Antelope-brush habitats and other natural ecosystems in the region. Large multi-housing developments are being constructed (as of 2015) close to Haynes' Lease Ecological Reserve and in many of the remaining Antelope-brush habitats surrounding the Town of Osoyoos.

Natural System Modifications (low impact) (7)

Fire and fire suppression (7.1)

Frequent, low-intensity wildfires were likely once more common throughout Antelope-brush habitats (Daigle 1996; Young and Clements 2002). Fires were likely ignited by First Nations peoples to improve root crops, and by lightning (Iverson 2012; Cannings and Durance 1998). Fire suppression activities have altered the natural fire regime in the Okanagan Valley, however, and appear to have increased fire intensity and severity (Iverson 2012). Larger stand-replacing fires may result, rather than smaller, less intense surface and patchy fires that otherwise leave Antelope-brush plant community patches intact.

Antelope-brush is very susceptible to fire-kill, with few plants re-sprouting following fire (Zlatnik 1999). After fire, Antelope-brush plants may persist in rocky refugia or in the skips of a patchy burn (Krannitz and Mottishaw 2003); these remaining individuals and any other survivors may also provide a seed source to re-establish Antelope-brush in adjacent areas (Young and Clements 2002; Shatford 1997).

A large (3000+ ha) fire burned much of the Antelope-brush habitat southeast of Vaseux Lake in early September 2003 (BC Ministry of Environment unpublished data) (Figure 7), including one of the two known sites for Nuttall's Sheep Moth (Vaseux Lake South). Although they were abundant there in 2002, Nuttall's Sheep Moths have not been observed at Vaseux Lake since the fire. A large fire also burned all but the southernmost 1/5 of Haynes' Lease Ecological Reserve in 1993, killing approximately 95% of the Antelope-brush (Roemer 1993). Antelope-brush is now relatively abundant at the site, but Nuttall's Sheep Moth has not been observed there since the fire. High-intensity fires, even of small size, could potentially have significant impacts on localized populations of Nuttall's Sheep Moth due to highly fragmented landscapes in the south Okanagan. Invasive non-native plants such as Cheatgrass increase the amount of fine fuels in Antelope-brush plant communities.

Tree encroachment, in the absence of frequent fire, may have also reduced the size and extent of Antelope-brush plants at some sites, due to shading and competition.

Energy Production and Mining (negligible impact) (3)

Mining and quarrying (3.2)

Gravel extraction is a localized threat to the Nuttall's Sheep Moth habitat. Several small gravel pits are located at or near the known Vaseux Lake sites, although it is not known if they are active.

Transportation and Service Corridors (negligible impact) (4)

Construction of new roads (4.1) and utility and service lines (4.2) have the potential to destroy or fragment Antelope-brush habitat upon which Nuttall's Sheep Moth depends.

Human Intrusions and Disturbance (negligible impact) (6)

Human intrusion and disturbance are likely only a minor threat. Caterpillars have stinging spines and adults are very swift flyers so are unlikely to be directly disturbed by recreationalists or other backcountry users. All-terrain vehicle use may have a local effect on habitat but is not permitted at known extant sites.

Invasive and Other Problematic Species and Genes (negligible impact) (8)

Invasive non-native/alien species (8.1)

Many non-native plant species are found throughout Antelope-brush ecosystems, and some appear to have little impact on the ecosystem (Symonds 2011). However, invasive non-native species such Cheatgrass (*Bromus tectorum*), Sulphur Cinquefoil (*Potentilla recta*), Diffuse Knapweed (*Centaurea diffusa*), and Dalmatian Toadflax (*Linaria genistifolia* ssp*. dalmatica*) can have significant adverse impacts on the Antelope-brush habitats (Iverson 2012) upon which Nuttall's Sheep Moth is dependent. For example, Sulphur Cinquefoil can form monospecific stands and may prevent re-establishment of Antelope-brush plants after wildfires (SIRT 2008).

Parasitoid tachinid flies such as *Compsilura concinnata* (Tachinidae) introduced into eastern North America as biological control agents for European Gypsy Moth (*Lymantria dispar*) have also impacted native Lepidoptera populations including *Hemileuca* (Boettner *et al.* 2000). *C. concinnata* is the most likely cause of the reported decline of giant silk moths in the northeastern United States (Elkinton and Boettner 2012), and although it has been reported from British Columbia (Sabrosky and Reardon 1976), possible effects on Nuttall's Sheep Moth are unknown. *Compsilura concinnata* was assessed as a possible bio-control agent for Cabbage Looper (*Trichoplusia ni*, Lepidoptera: Noctuidae) infesting commercial greenhouses in B.C., but its use was considered ineffective for greenhouse settings (Caron 2005).

Pollution (unknown impact) (9)

Agricultural and forestry effluents (9.3)

Presumed extant locations at Vaseux (Figure 9) and Haynes' Lease are immediately adjacent to vineyards so pesticide drift is a potential threat to larvae and adults. Agricultural fields are common in the Osoyoos and Oliver areas, as well as elsewhere in the Okanagan Valley. Drift of herbicides could potentially affect the larval host plant as well, although it is unknown how susceptible Antelope-brush is to commonly used agrochemicals.

Figure 9. GoogleEarth image (8/3/2012) of Nuttall's Sheep Moth record (S. Ife) east of Vaseux Lake showing vineyards, aggregate extraction, and residential development surrounding remaining Antelop-brush habitat.

Climate Change and Severe Weather (unknown impact) (11)

Droughts (11.2)

Climate change, particularly an increase in the frequency and intensity of extreme and periodic climatic events such as droughts, could be a long-term threat to Canadian populations of Nuttall's Sheep Moth. Decreased precipitation and increased mean annual temperatures associated with climate change might reduce host plant fitness and abundance in the short-term, but might also lead to an eventual northward range extension of Antelope-brush.

Climate change is a potential but poorly understood threat to Nuttall's Sheep Moth in the south Okanagan, primarily due to potential impacts on Antelope-brush habitats. In particular, an increase in the frequency and intensity of summer drought could result in premature senescence of larval host plants, or may change rain patterns during the larval period, potentially reducing juvenile survival. Although climate suitability for Antelope-brush grasslands in Canada could potentially increase as a result of climate change (Wilson and Hebda 2008), range expansion is unlikely given the current rates of habitat loss and low rates of dispersal for both Antelope-brush and Nuttall's Sheep Moth.

Storms and flooding (11.4)

Small, isolated populations of Nuttall's Sheep Moth are likely vulnerable to stochastic events and could be threatened by hailstorms or severe frost, particularly if the frequency and intensity of severe weather events increases due to climate change.

Limiting Factors

Canadian populations of Nuttall's Sheep Moth are vulnerable due to their small population size, short adult life span, non-feeding adult life stage, host plant specificity, and specific Antelope-brush plant community habitat requirements.

Number of Locations

Three locations are proposed for Nuttall's Sheep Moth in Canada based on a combination of threats and land tenure: (i) The Vaseux Lake area has areas that are protected (e.g., The Nature Trust of B.C., Vaseux Bighorn National Wildlife Area) but there could be potential effects from wildfire and the overgrazing of livestock on other Crown and private properties; (ii) The Oliver area is perceived to be at greater risk of residential and agricultural (e.g., vineyard) development; and (iii) the Osoyoos area has some substantial Antelope-brush communities on First Nation lands and the smaller Haynes' Lease Ecological Reserve, but other areas have been heavily developed. Haynes' Lease Ecological Reserve is threatened by wildfire.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

The Nuttall's Sheep Moth is not protected under the federal *Species at Risk Act* or British Columbia's *Wildlife Act*. It is not listed under the US *Endangered Species Act* or the Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Non-Legal Status and Ranks

Global status rank: G5 (Secure; NatureServe 2014).

Canada national status rank: Not ranked.

British Columbia status rank: Not ranked. United States, state ranks: Colorado S4 (Apparently Secure); Not ranked in the other nine states where it occurs.

General status rank: *May be at Risk* in the WildSpecies (2010) report (CESCC 2011).

Habitat Protection and Ownership

The most recent Nuttall's Sheep Moth observations have been from protected areas. The 1975-76 and 2002 records from the Vaseux Lake area are on The Nature Trust of B.C. properties and the 1986 Osoyoos record was from Haynes' Lease Ecological Reserve (BC Parks). The precise localities of other historical collections from Osoyoos and Oliver are unknown, but given current land tenure, there is a high probability they are on either private or First Nation land.

About 17% of the remaining Antelope-Brush / Needle-and-Thread Grass vegetation community is protected by the Canadian Wildlife Service National Wildlife Areas (3%), provincial Protected Areas (6%), and private conservation lands (8%) (Iverson 2012). The remaining 83% occurs in unprotected lands on Indian Reserves (56%), private land (20%), and provincial crown land (6%).

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BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Robert Foster is co-founder and principal of Northern Bioscience, an ecological consulting firm offering professional consulting services supporting ecosystem management, planning, and research. Dr. Foster has a B.Sc. in Biology from Lakehead University and a D. Phil in Zoology from the University of Oxford. Rob has worked as an ecologist in Ontario for over 20 years, and has authored or coauthored COSEWIC status reports on the Bogbean Buckmoth, Mormon Metalmark, Weidemeyer's Admiral, Powesheik Skipperling, Lake Huron Grasshopper, Riverine Clubtail, Laura's Clubtail, Rapids Clubtail, Gibson's Big Sand Tiger Beetle, Northern Barrens Tiger Beetle, Hop-tree Borer, Georgia Basin Bog Spider, Broad-banded Forestsnail, Nahanni Aster, Crooked-stem Aster, Bluehearts, and Drooping Trillium, as well as recovery plans for rare plants, lichens, and odonates. Rob has conducted numerous odonate and other insect surveys for protected areas planning and environmental assessments in Ontario, as well as Manitoba, Minnesota, Quebec, and British Columbia.

Allan Harris is a biologist with over 25 years' experience in northern Ontario. He has a B.Sc. in Wildlife Biology from the University of Guelph and an M.Sc. in Biology from Lakehead University. After spending seven years as a biologist with the Ontario Ministry of Natural Resources, he co-founded Northern Bioscience, an ecological consulting company based in Thunder Bay, Ontario. Al has authored or coauthored dozens of scientific papers, technical reports, and popular articles, including COSEWIC status reports for Lake Huron Grasshopper, Riverine Clubtail, Laura's Clubtail, Rapids Clubtail, Gibson's Big Sand Tiger Beetle, Northern Barrens Tiger Beetle, Powesheik Skipperling, Mormon Metalmark, Weidemeyer's Admiral, Bogbean Buckmoth, Hop-tree Borer, Georgia Basin Bog Spider, Broad-banded Forestsnail, Nahanni Aster, Crooked-stem Aster, Bluehearts, Drooping Trillium and Small-flowered Lipocarpha. Al also authored the Ontario provincial status report for woodland caribou, and has authored or coauthored national and provincial recovery strategies for vascular plants and birds.

COLLECTIONS EXAMINED

The following collections were searched for Canadian specimens of Nuttall's Sheep Moth:

Canadian National Collection of Insects, Arachnids and Nematodes, Ottawa, ON (Owen Lonsdale)

Chicago Field Museum, Chicago, IL. (on-line search)

E.H. Strickland Entomological Museum, University of Alberta, Edmonton, AB (on-line search)

J.B. Wallis Museum, University of Manitoba, Winnipeg, MB. (Barb Sharanowski)

Royal Alberta Museum, Edmonton, AB. (Matthias Buck)

Royal British Columbia Museum, Victoria, BC. (Claudia Copley)

Royal Saskatchewan Museum, Regina, SK. (Cory Sheffield)

Spencer Entomological Collection, Beaty Biodiversity Museum, University of British Columbia, Vancouver BC (Karen Needham)

Yale Peabody Museum of Natural History, New Haven, CT (on-line search)